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Biological & Environmental Research

ASP Highlights

FY 2009 ASP Science Team Meeting
February 25-27, 2009
Santa Fe, NM

Ashley D. Williamson
ASP Program Manager
Climate & Environmental Science Division
Biological & Environmental Research
Office of Science

February 25, 2009

Program News and Events

- Participation in ARM ISDAC IOP - 2/08
- Conducted BC/ARI Soot Experiment II - 7/08
- Multiagency VOCALS Campaign – 10/08
- Selected CARES 2010 campaign
- Draft ASP Model Strategy Document, 12/08
- Beginning work on ASP/ARM Science Plan, June 2009 completion

ASP Highlights

- Horizon – last 5 years
- My emphasis
  - How they fit our mission (since 2004 reconfiguration)
  - How they relate to climate science needs
  - How they fit together
  - How they relate to the ASP/ARM Science Plan

BERAC RECOMMENDATIONS IMPLEMENTED IN ASP RECONFIGURATION

“ Reconfiguring the ASP to a program emphasizing ***radiative forcing of climate from aerosols*** has great merit … and as such should be implemented as soon as practical.

“ A well-balanced program consisting of ***field*** measurements, ***laboratory*** experiments, ***theoretical*** analysis with process ***modeling***, and development and application of new ***instrumentation*** will be required.

“ The reconfigured ASP should have as its goal the reduction of uncertainties in two specific gap areas. These are (1) ***the indirect effects of aerosols on clouds*** and (2) ***the role of black carbon and organic carbon aerosols on climate forcing***.

“ The reconfigured ASP needs to be ***closely coordinated with the DOE Atmospheric Radiation Program (ARM) program*** and vice-versa as well as collaboration with other stakeholder programs in order to make most effective use of limited resources.

“ The reconfigured ASP should look to the ***climate modeling program within DOE*** and the larger Climate Change Science Program (CCSP) as a test bed for ***applying knowledge and parameterizations*** gleaned both from the reconfigured ASP and the ARM programs.

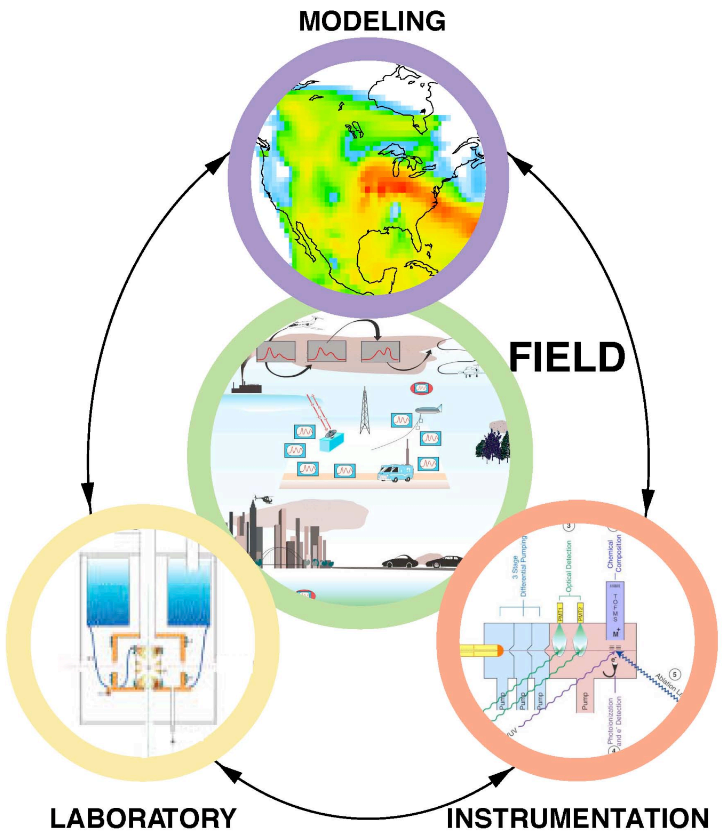
-- *A Reconfigured Atmospheric Science Program: DOE Biological and Environmental Research Advisory Committee, April 2004*

Atmospheric Science Program - methodology

Portfolio:

A coordinated mix of activities to investigate key atmospheric physical processes:

- Laboratory studies of basic processes
- Field campaigns for "real world" observations and to validate model predictions
- Model-based representations of processes (develop, implement, and validate)
- Measurement instrumentation / method development



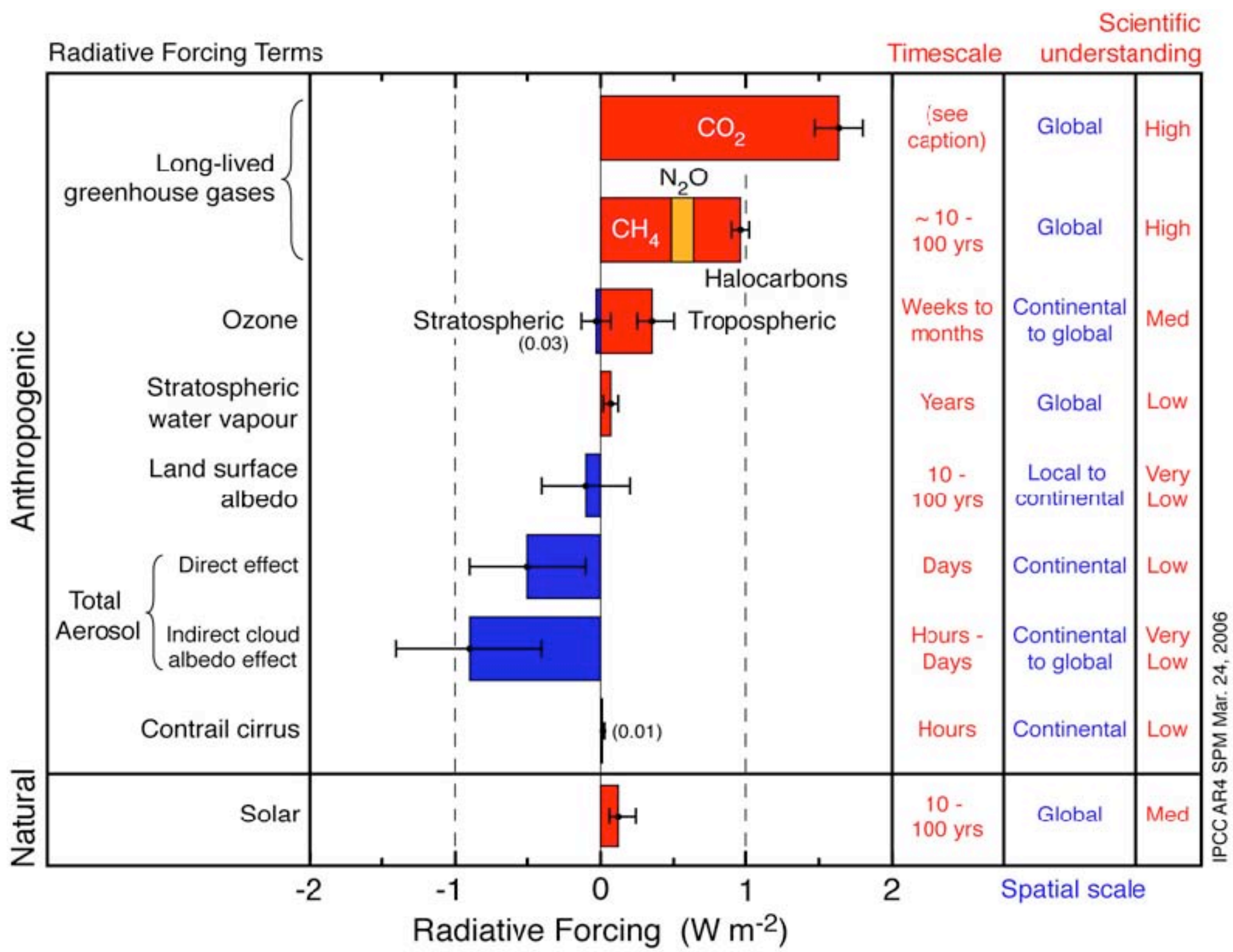
Impact: **Improved instruments, process understanding, and models**

ASP Mission areas

… radiative forcing of climate from aerosols

… goal the reduction of uncertainties in two specific gap areas. These are (1) ***the indirect effects of aerosols on clouds*** and (2) ***the role of black carbon and organic carbon aerosols on climate forcing***. …[consider] the ***climate modeling program within DOE*** …a test bed for ***applying knowledge and parameterizations***

Aerosol forcing challenges



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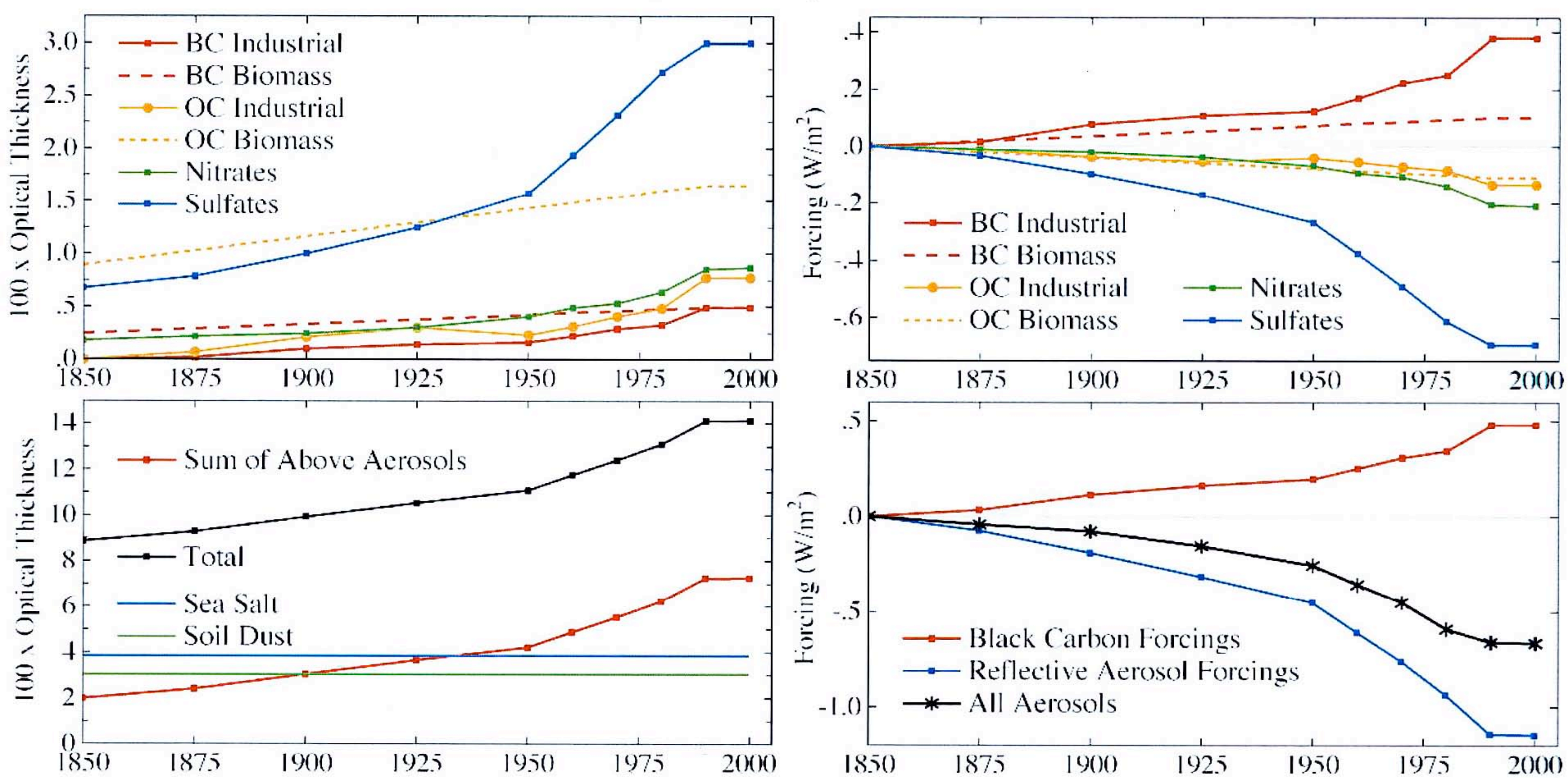
Aerosol impacts- Why study # 4 & 5?

Table 1.1. Estimated source strengths, lifetimes, mass loadings, and optical depths of major aerosol types. Statistics are based on results from 16 models examined by the Aerosol Comparisons between Observations and Models (AeroCom) project (Textor et al., 2006; Kinne et al., 2006). BC = black carbon; POM = particulate organic matter.

	Total source[1] ($Tg\ yr^{-1}$)	Lifetime (day)	Mass loading[1] (Tg)	Optical depth @ 550 nm
	Median (Range)	Median (Range)	Median (Range)	Median (Range)
Sulfate[2]	186 (100 – 233)	4.1 (2.5 – 5.4)	2.0 (0.92 – 2.7)	0.034 (0.015 – 0.051)
BC	11.3 (7.8 – 19.5)	6.5 (5.3 – 15)	0.21 (0.046 – 0.51)	0.004 (0.002 – 0.009)
POM[2]	96.0 (53 – 138)	6.2 (4 – 11)	1.8 (0.46 – 2.56)	0.019 (0.006 – 0.030)
Dust	1640 (700 – 4000)	4.0 (1.3 – 7)	20.5 (4.5 – 29.5)	0.032 (0.012 – 0.054)
Sea-salt	6280 (2000 –120000)	0.4 (0.03 – 1.1)	6.4 (2.5 – 13.2)	0.030 (0.020 – 0.067)
Total				0.127 (0.065 – 0.15)

[1]Tg (teragram) = 10^{12} g, or million metric tons.
[2]The sulfate aerosol source is mainly SO_2 oxidation, plus a small fraction of direct emission. The organic matter source includes direct emission and hydrocarbon oxidation.

Aerosol forcing challenges – OC and especially BC have significant forcing impacts

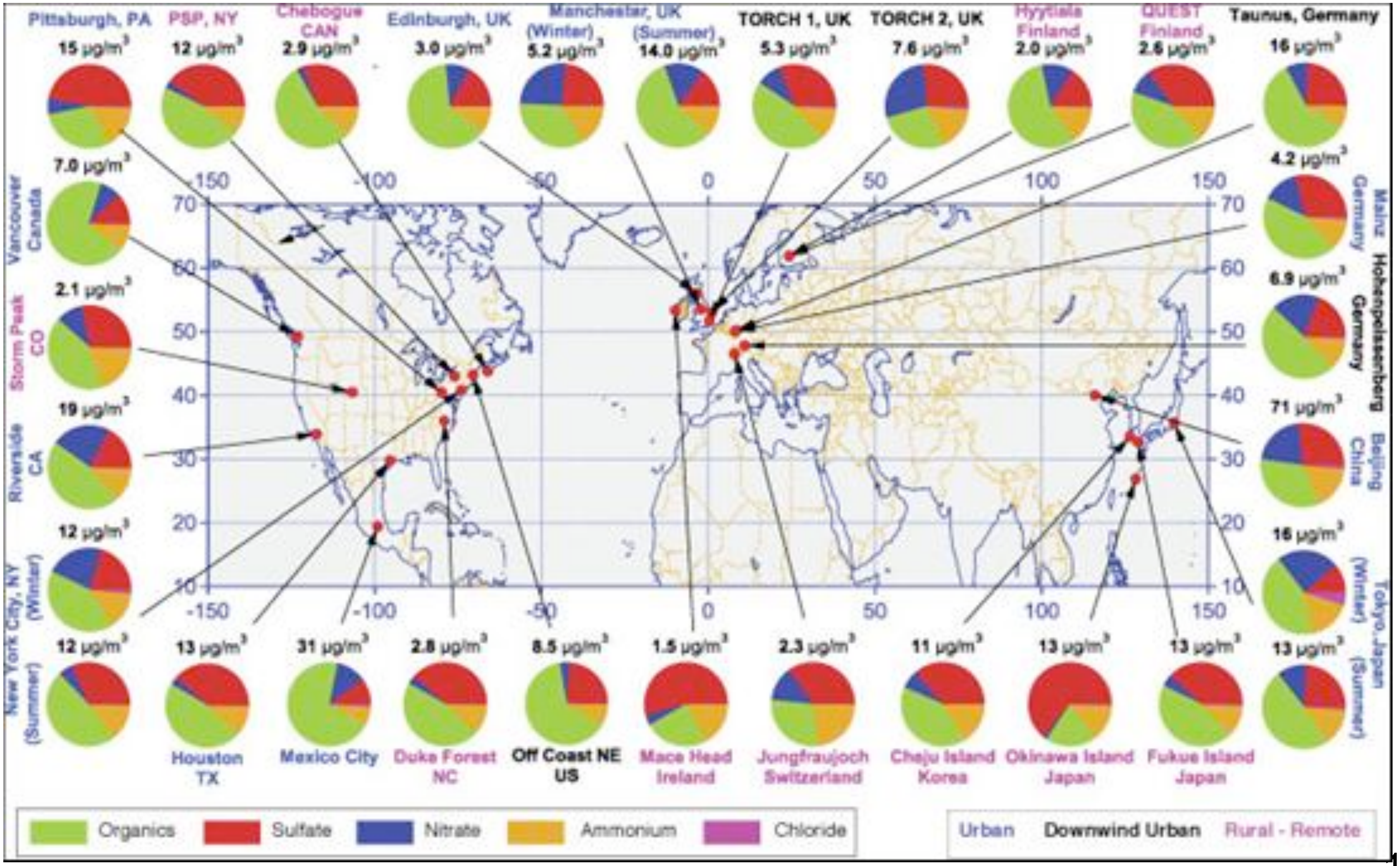


Hansen, J. et al., 2007: Clim. Dyn. 29:661-696.

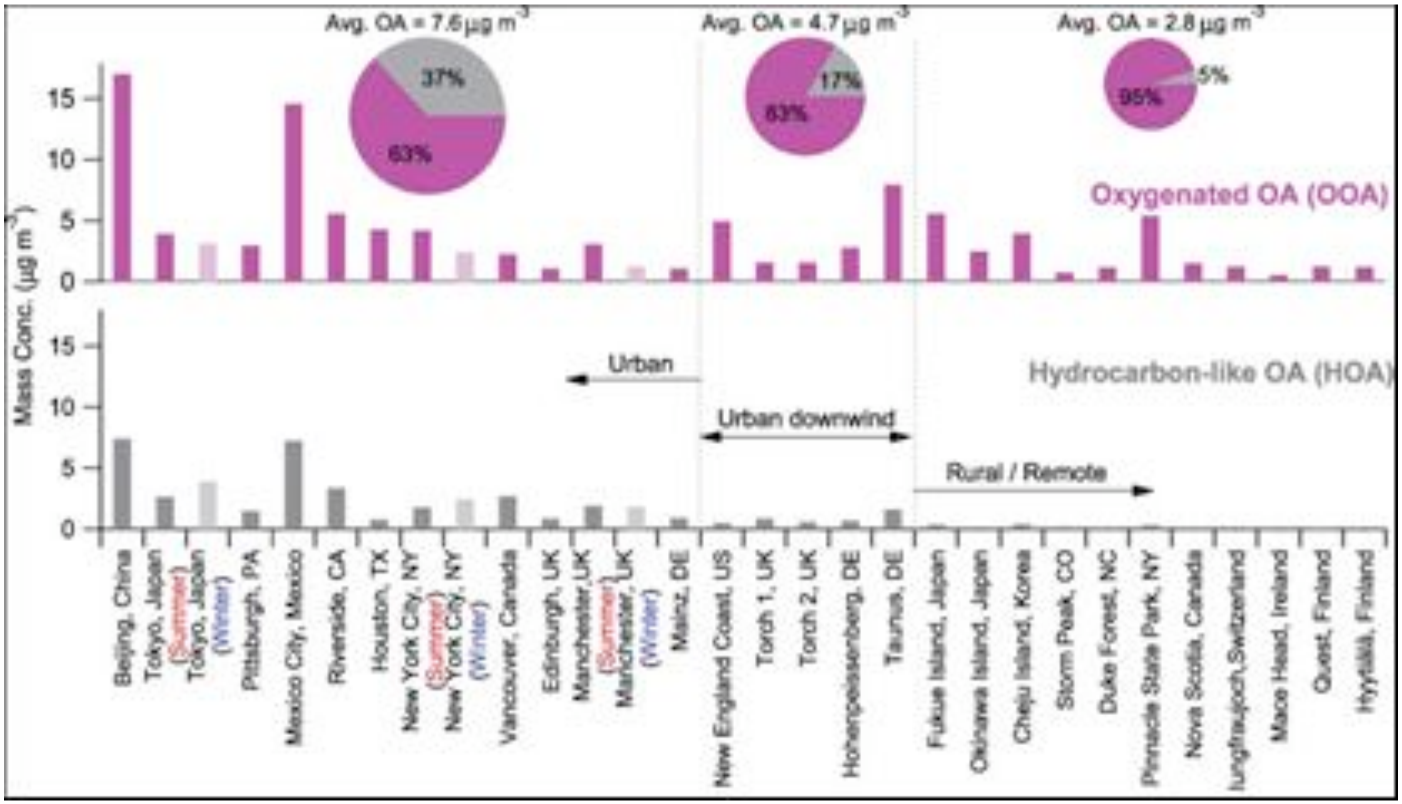
Organic Carbon Issues

- "Missing SOA" – globally observed SOA in great excess of predictions
  - Interaction of biogenic and anthropogenic source factors
  - Interaction with gas phase VOC, SVOC
- Complexity of composition and properties
  - Optical properties, phase state and hydration behavior, volatility/reactivity
- Representation in CTMs and GCMs

Organic Aerosol is widespread …

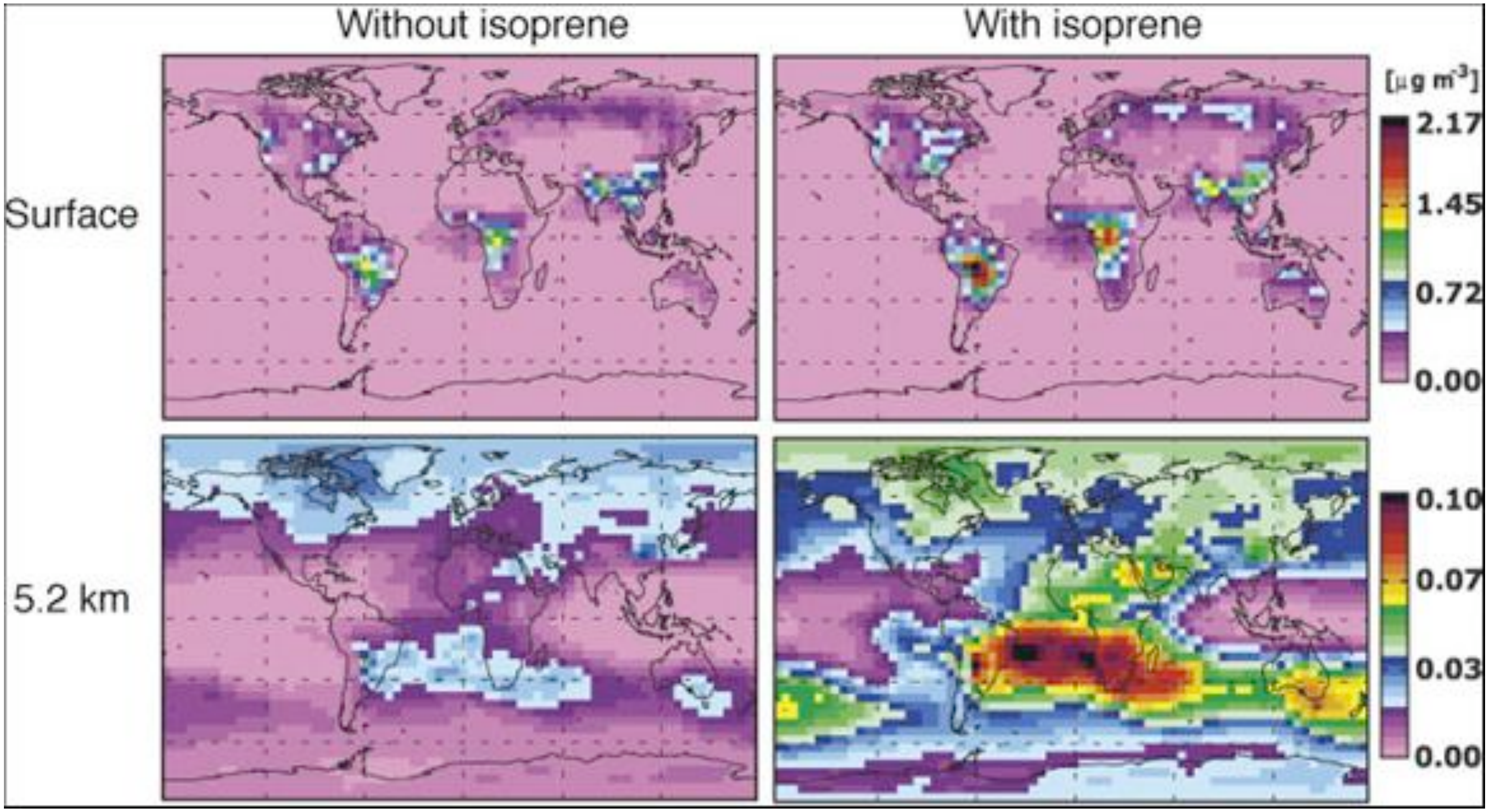


… and variable in composition



Zhang Q., et al., Geophys. Res. Lett., 34, L13801, doi:10.1029/2007GL029979

Isoprene found to be an underestimated source



Henze, D. K. and Seinfeld, J. H. Geophys. Res. Lett. 33, L09812, doi:10.1029/2006GL025976 (2006).

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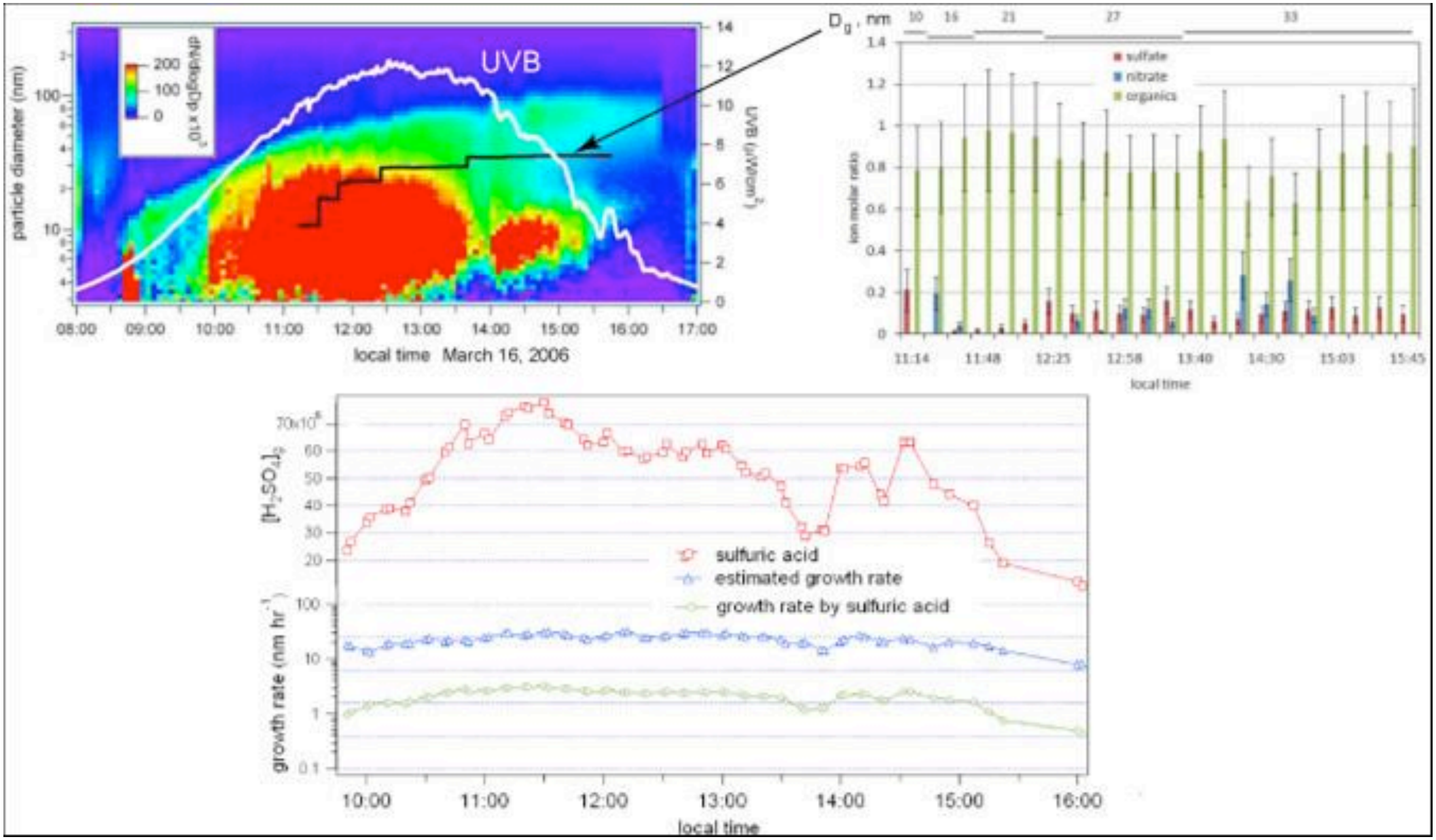
SOA influences New Particle Formation



Smith, et al., Geophys. Res. Lett. 35, L04808, doi:10.1029/2007GL032523 (2008)

ASP response to Organic Carbon Issues

- "Missing SOA" – problem definition
  - Lab Studies of SOA formation mechanisms
  - Lab Studies of SOA properties (optical, hydration)
  - Field studies of anthrogenic, biogenic SOA
- Complexity of composition and properties
  - Lab, field and theoretical studies
- Representation in CTMs and GCMs
  - SOA chemistry in regional, global CTMs
  - Closure studies

“Black Carbon”/Absorbing Aerosol Issues

- Measurement issues complicate separation from other aerosol species
- “Aging” alters properties during lifetime
  - Optical, hydration and phase state, volatility/reactivity
- Positive forcing impact requires separate accounting to separate impacts
  - Semidirect effects, snow albedo, water cycle
- Representation in CTMs and GCMs

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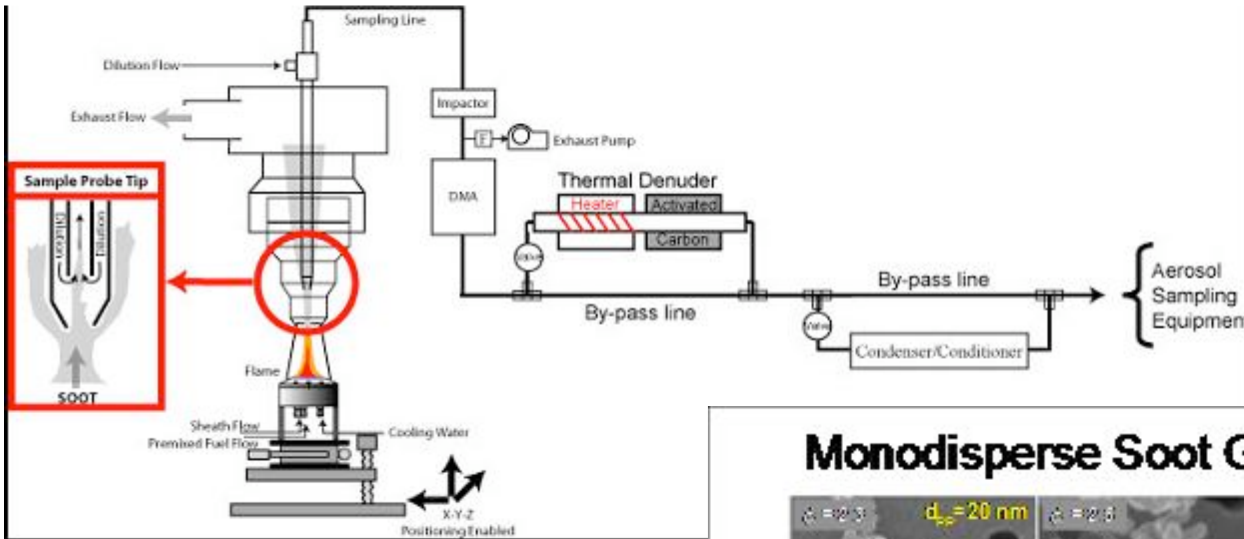
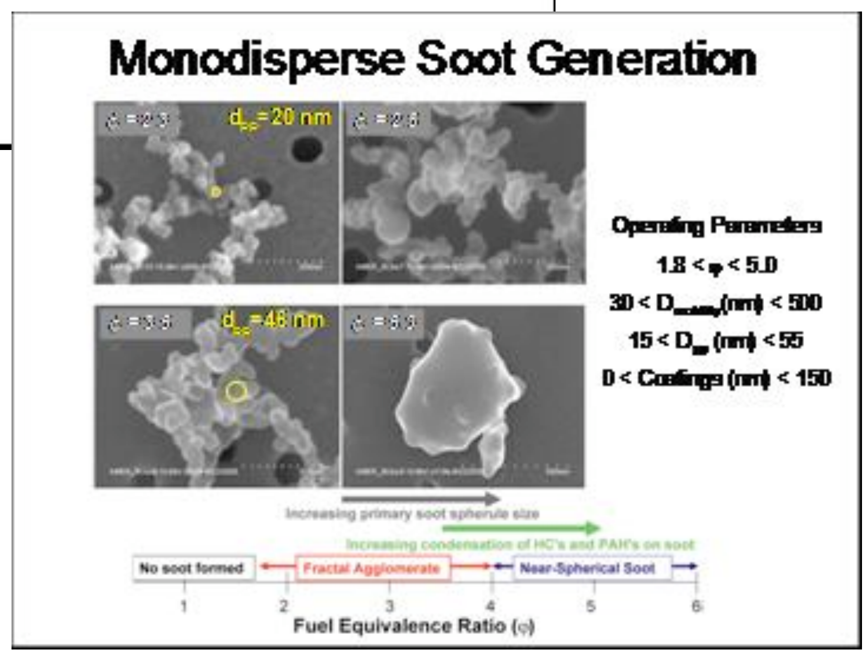
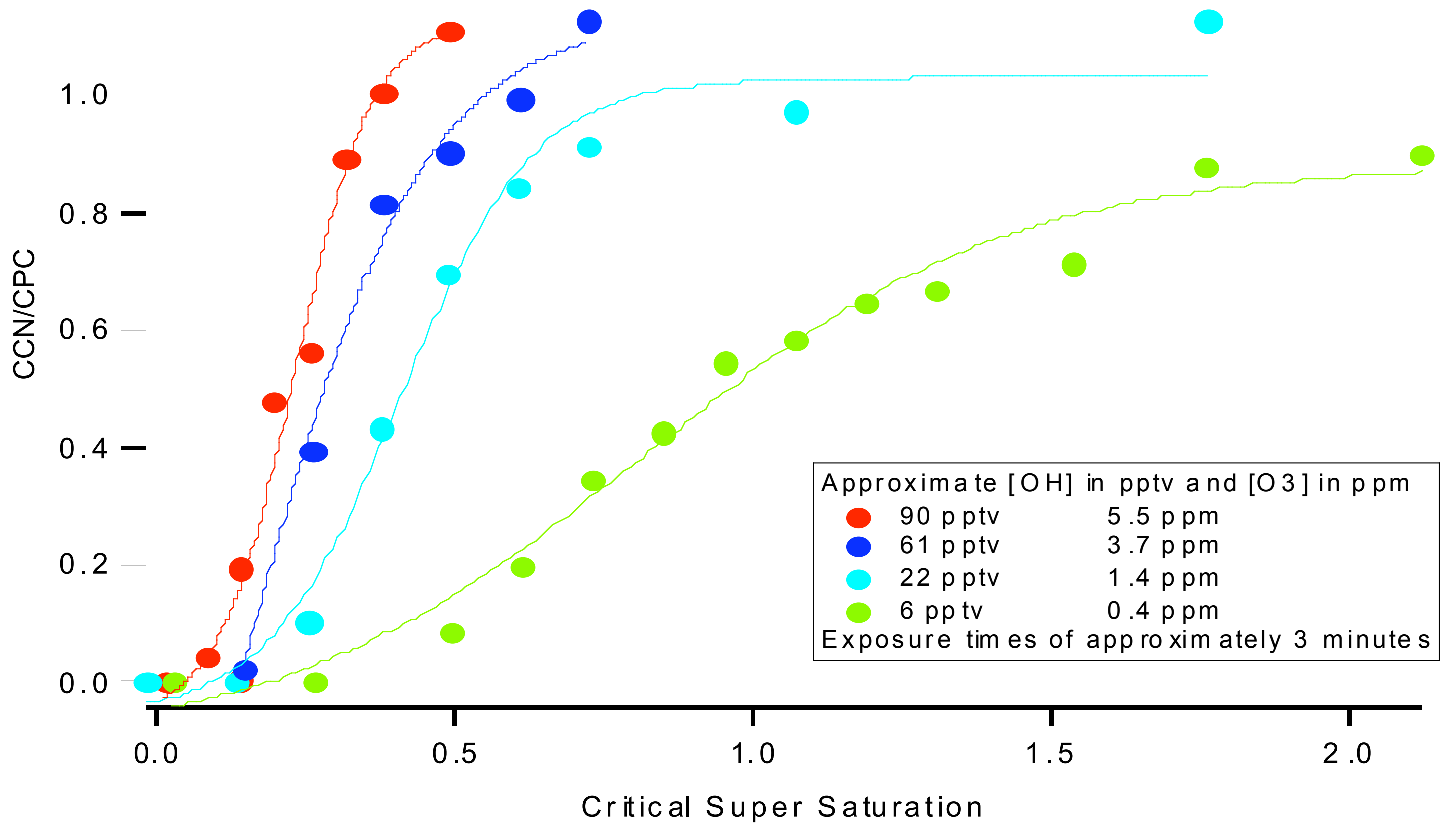
BC “Black Carbon Lab” venue for several studies





“Aged BC” becomes more CCN active



"Black Carbon"/Absorbing Aerosol Response

- Measurement issues – measurement technique development and evaluation (BC intercomparisons, instrumental projects)
- "Aging" effects on properties
  - Lab projects on optical, hydration/CCN properties of BC, SOA, and mixtures
  - Field investigations of properties and evolution
  - Life cycle impacts
- Representation in CTMs and GCMs
  - Some BC – cloud interactions modeling

Indirect Effect (Cloud-Aerosol Interaction) Issues

- *What is ASP's role in all of this …*
- Quantitative assessments of indirect effects will require:
  - Improved Aerosol- and Cloud-microphysics process understanding
  - Observational findings of aerosol impacts on cloud behavior and radiative interactions (ARM's strong suit)
  - Global observations of aerosol and cloud behavior (all hands …)
  - Comparison of model and observational results
- ASP capabilities include (at least):
  - Aerosol – water interactions vs. size and composition
  - Particle and droplet optical properties
  - Cloud chemistry and aerosol-cloud interactions
- How do we address the other pieces?

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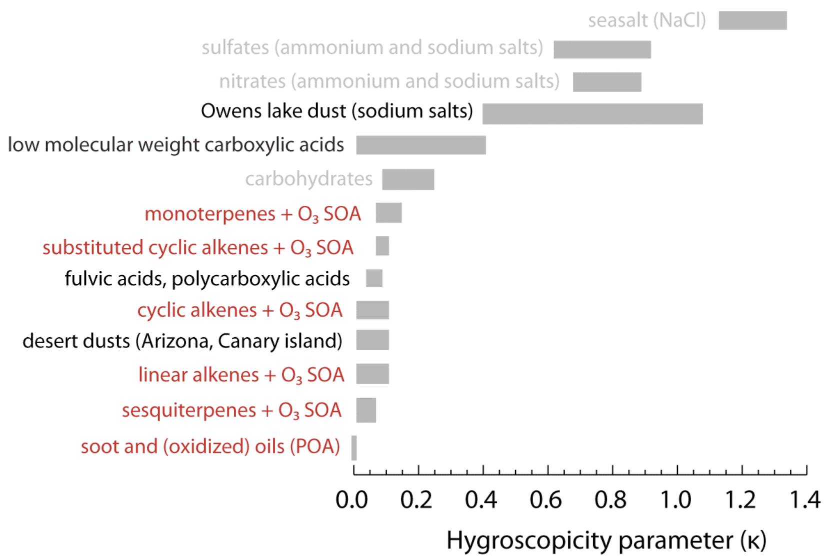
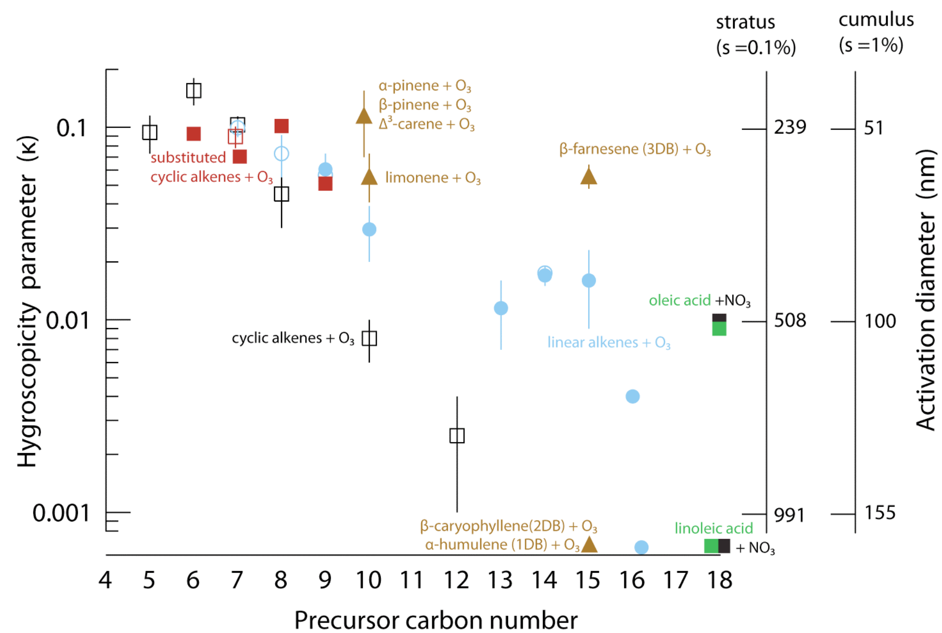
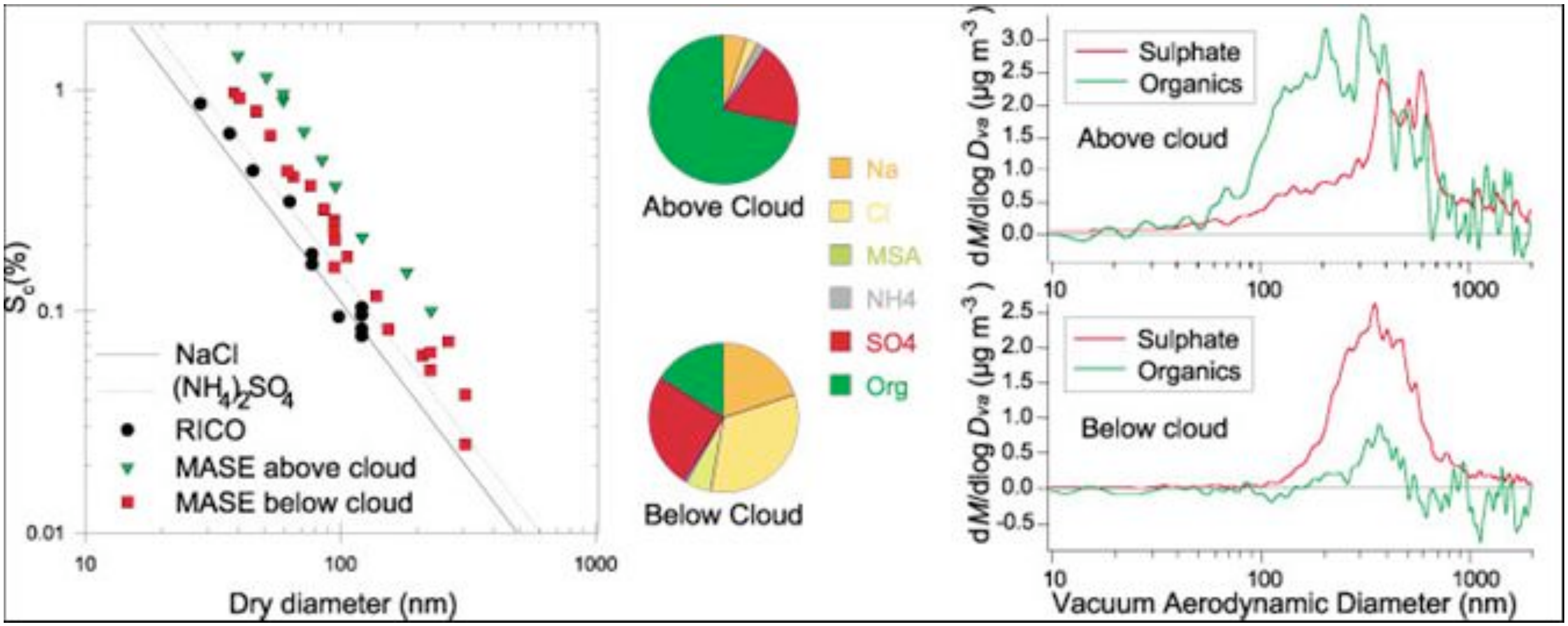
Hygroscopic effects parameterized vs. organic aerosol components





Prenni, A. J., et al. (2007), J. Geophys. Res., 112, D10223; Petters, M. D., et al.(2006), Geophys. Res. Lett., 33, L24806, doi:10.1029/2006GL027249.

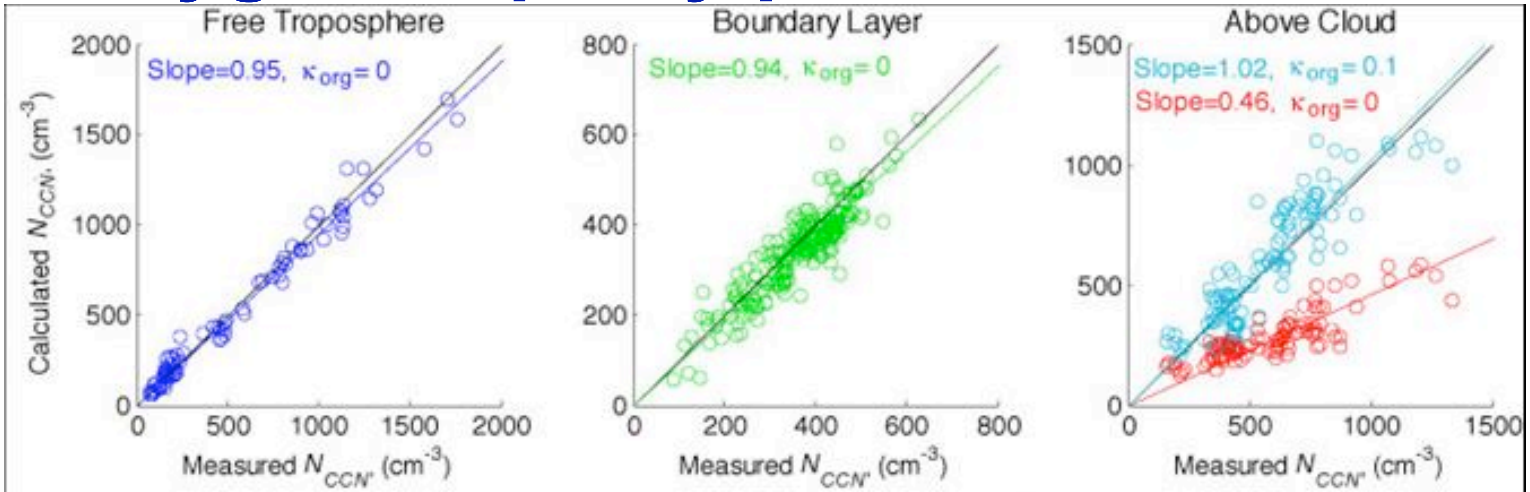
MASE Data show composition effects on CCN activation



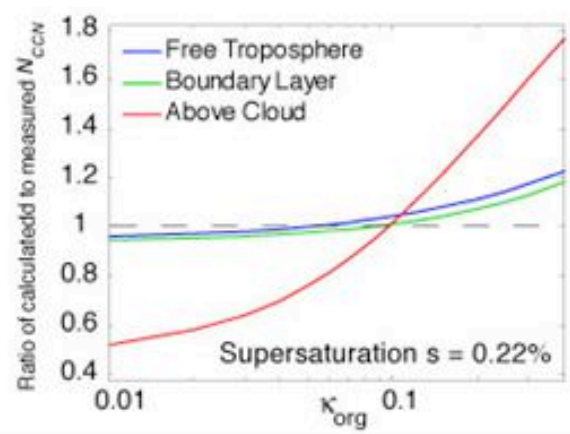
Size matters – but chemistry matters too.

Measurements of J. Hudson, Y.-N. Lee, and M. Alexander.

MASE Data show closure fit to hygroscopicity parameterization



$$S=\frac{D^3-D_p^3}{D^3-D_p^3(1-\kappa)}\exp\left(\frac{4\sigma_w M_w}{RT\rho_w D}\right)\qquad \kappa=\sum_i x_i\kappa_i$$

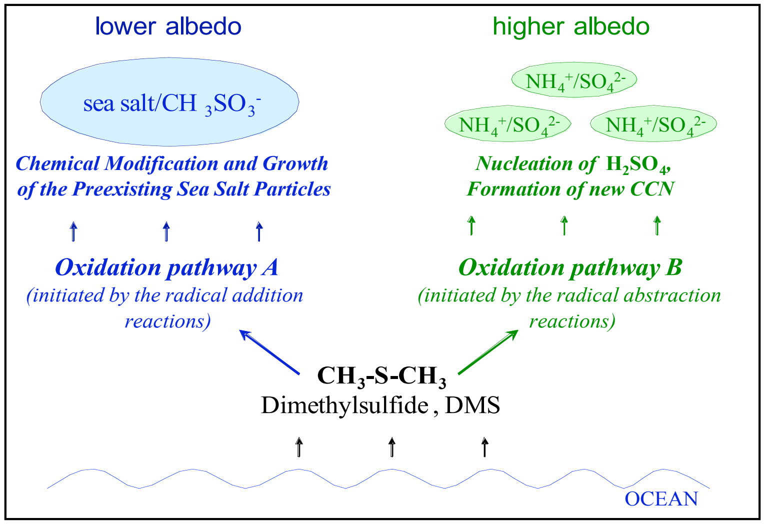


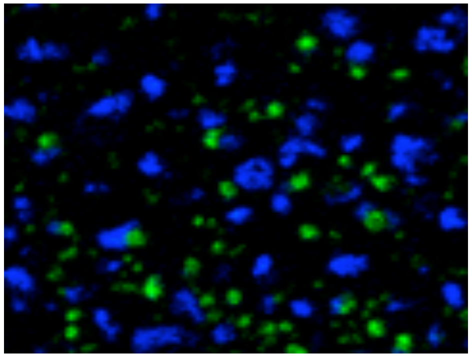
Wang. J., et al. 2008, Atmos. Chem. Phys., 8, 6325-6339.

Chemical Speciation of Sulfur in Marine Cloud Droplets

LBNL (R.J. Hopkins, PI: M.K. Gilles), *PNNL* (Y. Desyaterik, PI: A. Laskin)

- **Partitioning of $CH_3SO_3^-$ and SO_4^{2-} in individual droplets is of key importance to understand the impact of Sulfur Chemistry on Climate Change in marine areas**





TOF-SIMS imaging of SeaSalt/$CH_3SO_3^-$ and NH_4^+/SO_4^{2-} residues of cloud droplets

- Chemical speciation and apportionment of sulfur containing compounds have been facilitated by a complementary combination of novel analytical techniques hosted by two DOE user facilities: TOF-SIMS and CCSEM/EDX (*EMSL of PNNL*) and STXM/NEXAFS (*ALS of LBNL*).

- Excessive formation of SeaSalt/$CH_3SO_3^-$ over NH_4^+/SO_4^{2-} has been demonstrated under cold cloud conditions typical for the area.

- Reported data include values of $CH_3SO_3^-$/nss-SO_4^{2-} ratios measured in individual Sea Salt particles

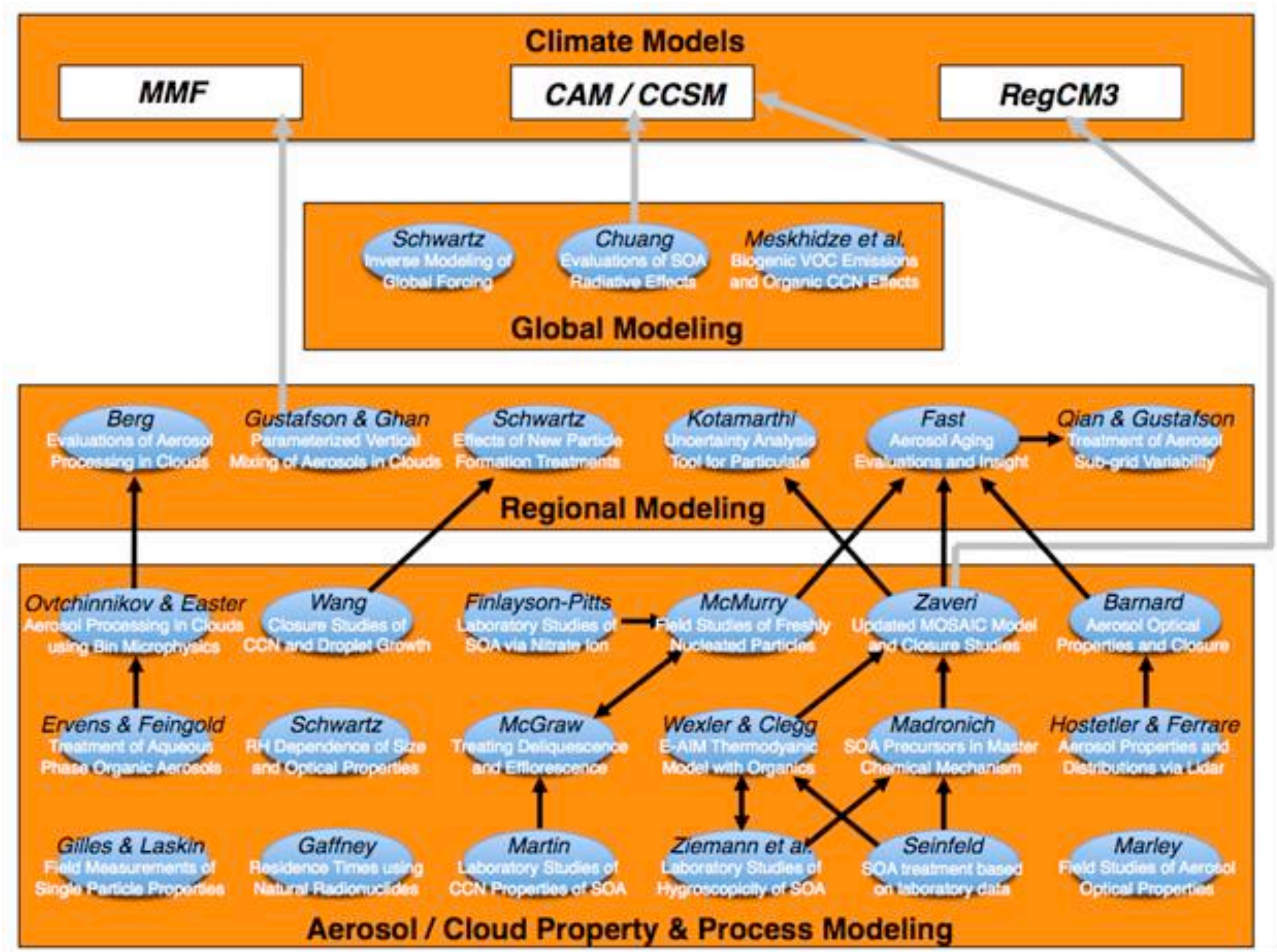
Indirect Effect (Cloud-Aerosol Interaction) Results

- Lab studies of aerosol – water interactions and effects on properties
- In-situ field studies of aerosol impacts on cloud behavior (MASE, CHAPS, VOCALS, and some of ISDAC
  - Comparison of model and observational results
- Model development on cloud-aerosol processes, autoconversion, now in-cloud chemistry
- *How do we address the other pieces?*

Modeling Issues

- *How to make it happen …*
- "Aerosols are complicated - What is the least that I need to know to predict climate impacts with acceptable accuracy?"
- "Two-model" strategy for atmospheric processes
  - Robust CTMs needed for closure expts., process model development & sensitivity studies, adequate representation of effects, computational feasibility, GCM inputs
  - Coupled GCMs need well-behaved modules of tractable complexity

ASP Model Portfolio



What next?

- ASP has made needed contributions in all these areas, and more should come in next few years as new projects mature
  - Carbonaceous aerosol activity high and productive
  - Some contributions re: indirect effects, but problem is way bigger than ASP (and ARM)
  - Good progress in model components, but we are really not playing in this field as we should be
- ASP needs strategy and concerted effort to optimize our output, especially in regards to cloud-aerosol interactions and partnership with the climate modeling community
  - ASP/ARM Science Plan to shape interactions with ARM Science
  - Build on ASP Model Strategy